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Transfer of development rights, farmland preservation, and economic growth: a case study of *Chongqing's* land quotas trading program

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ABSTRACT

The dilemma between preserving farmland and urbanization has attracted many policymakers' attention. One sound solution that has been practiced in several developed countries is the "transfer of development rights" (TDR). This study examines a specific TDR program in China—the Chongqing Land Quotas Trading program. We use a synthetic control method on the 2001–2014 statistics of 57 prefectures to quantitatively assess the program's effect on farmland preservation and economic growth. A mixed method, including both satellite image analysis and qualitative interviews, was also used to obtain some intuitive evidence to understand the mechanism of this program. We find that the Chongqing TDR program has substantially reduced the loss of farmland and played a significant role in stimulating economic growth. We argue that the use of TDR might effectively address the farmland preservation and urbanization dilemma in China.

1. Introduction

Fast urbanization in many developing countries, accompanied by massive migration outflow, has dramatically changed land utilization in both urban and rural areas worldwide (Cohen, 2004; Cotula and Neve, 2007; Bhat et al., 2017; Mosammam et al., 2017). According to the recently published *United Nation World Urbanization Perspective* (2018), a significant share of urbanization will come from developing countries (e.g., India, China, and many sub-Sahara African countries). Policymakers in almost all developing countries believe that urbanization is an effective way to achieve economic growth and social transformation (Yusuf and Saich, 2008).

A direct consequence of massive urban expansion is large amounts of farmland around urban fringes being converted into construction land for housing, manufacturing-related expansion, and metropolitan open-space programs for urban dwellers (Bunce, 1998; Yeh and Li, 1999; Firman, 2000). Thus, loss of farmland has become an emerging concern (Chien et al., 2015; Martellozzo et al., 2015).[1] This is particularly the case in countries where ensuring food security with limited farmland is still a policy priority (Brockerhoff, 2000; Godfray et al., 2010).

How to preserve limited farmland and simultaneously meet the increasing demand for urban construction land has become a development dilemma. On the one hand, fast urbanization increases the demand for construction land. Without proper land development tools, this might lead to urban sprawl (Thorsnes and Simons, 1999; Brueckner, 2000), which can be an excessive waste of peri-urban land. On the other hand, massive migration outflow without a proper land sales market might lead to wasting rural construction land (Reichert-Schick, 2010; Sun et al., 2011).

Conventional land use planning tools, such as comprehensive land use planning and/or zoning, are often seen as ineffective and costly to implement (Linkous, 2017; Wright and Czerniak, 2000). In some cases, these instruments are not even feasible when there are no well-defined land property rights.[2] For instance, zoning is the most often employed land development tool in public policy (Dietderich, 1996; Chiodelli and Moroni, 2016). Criticisms on zoning include its negative environmental externalities due to urban sprawl (e.g., pollution and waste of farmland), socioeconomic segregation effects (rich vs. poor), and negative impact on quality of life (Hall, 2006; Rothwell and Massey, 2009; Wickersham, 2000).

To better utilize limited farmland or preserve nature, and meet the growing demand of urban construction land, a more market-oriented, voluntary, and financially compensated approach—transfer of land

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[1] The cost associated with "reconverting" urban construction land back to agricultural use is prohibitively high; it is almost impossible to implement such a "recovery" policy.

[2] For instance, land property rights are rather weakly defined and are often not well-protected.

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development rights (TDR)—has become increasingly popular worldwide (Gabriel and Freeman, 1986; Cho, 2002; Henger and Bizer, 2010; Wang et al., 2010; Menghini et al., 2015). Since the first TDR program was implemented in New York City in the 1960s (Richards, 1972; Nelson et al., 2013), the idea has quickly spread to other developed economies (Machemer and Kaplowitz, 2002. For example, since the 1980s, Germany (Henger and Bizer, 2010), France (Renard, 2007), the Netherlands (Janssen-Jansen, 2008), and Italy (Falco and Chiodelli, 2018) have all operated several TDR programs for natural environmental preservation and/or urban redevelopment. Recently, some developing countries have also adopted this market-oriented approach to improve their land use efficiency and preserve their farmland or natural heritage (e.g., Brazil (Chomitz, 2004), China (Zhu, 2004; Wang et al., 2010), and India (Burra, 2005)).

Although the use of TDR has become more prevalent in developing countries, few programs have been rigorously evaluated. In theory, a successful TDR program can be implemented at any scale to achieve higher land use efficiency (Nelson et al., 2013). For instance, Linkous, 2016 showed that by transferring land development rights, *land-sending areas* could receive large compensation, which in return could stimulate regional *non-land-based* investments and consumption (Zhang et al., 2014). Meanwhile, *land-receiving areas* could achieve higher development density that in turn, could better stimulate regional economic growth (Levinson, 1997). However, critics often raise problems with existing land property rights and the land sales market in many developing countries (Triedman et al., 2014). Some argue that a well-developed and regulated TDR market requires not just land property rights, but also well-functioning credit and labor markets (Fulton et al., 2004).

In China, the rural–urban transformation has been massive since the socioeconomic reform in the 1980s (Tan et al., 2005; Liu et al., 2016; Yang et al., 2018). High-speed economic growth, accompanied by massive rural–urban migration and fast urbanization, has also created a significant shift in land use (Li and Long, 2015; Long et al., 2009, 2011). A particular concern about the change in land use focuses on high-quality farmland losses, which has significantly hindered sustainable urbanization and food security (Chen, 2007; Liu et al., 2010a; Long et al., 2018). Under current urbanization, rural villages in poor regions and remote areas have been hollowing gradually, and a substantial amount of rural construction land has been wasted (Liu et al., 2011, 2014; Liu and Li, 2017; Long et al., 2012, 2019). A land redevelopment plan concerning both rural and urban areas is needed. However, how to ensure balanced urban–rural development in terms of land utilization still demands more policy study (Liu et al., 2013).

Taking rural construction land as the focus, the experimental TDR program—the Land Quotas Trading (LQT) program—was promulgated in *Chongqing* in 2008 to address the emerging land use problem caused by the fast urbanization of, and massive emigration from, its rural areas. As a pilot program, the LQT program was designed with a market-oriented development rights exchange idea—the TDR concept—under China's current national land management system. It was designed to promote land use efficiency through the land development rights market and realize farmland preservation and economic development.

There is growing, multi-perspective literature on the *Chongqing* LQT program. For instance, Cai (2012) argued that the *Chongqing* LQT program is an institutional innovation of the local government to balance the conflict between ensuring continuous economic growth and fulfilling centralized land planning management requirements. Xiao (2014) explained the detailed operational mechanism of land quota generation and transfer processes, and analyzed its mixed welfare effects toward various types of farmers. Moreover, other scholars found that the *Chongqing* LQT program promotes rural land consolidation (Guo and Zhong, 2016), and its market-oriented mechanism reduces the chance of exploiting rural farmers (Sheng, 2011). It has also significantly optimized the relationship between population urbanization and land urbanization (Fang, 2017). However, few studies have been devoted to systematically analyzing the effects of the *Chongqing* LQT program on farmland preservation and economic growth.

This study documents the *Chongqing* LQT program and assesses the effect of this experimental TDR program on preserving farmland and stimulating economic growth in China.[3] Specifically, we first comprehensively document this program to provide a clear background of the program design and its operation under China's current land management system. Second, we quantitatively assess the effects of this program on farmland preservation and other socioeconomic outcomes (e.g., urban expansion, employment, and economic growth). Third, given the unique nature of China's land institution, we further discuss the potential non-economic concerns over this program and its policy implication for China's current rural vitalization and integrated rural–urban development. To achieve these objectives, we first provide a detailed illustration of the operation of the *Chongqing* LQT program and how it fits in China's current land management system. To quantitatively assess its effects, we collect statistics of 57 prefectures and use a synthetic control method (SCM), which has been widely used in comparative studies, to conduct an empirical analysis. We further conduct a mixed method analysis, in which we use both satellite image analysis and qualitative interviews, to provide some intuitive evidence on the mechanism of this program.

Our paper contributes to the literature in two ways. First, different from most of developed countries (Renard, 2007; Janssen-Jansen, 2008; Henger and Bizer, 2010) in which land is privately owned, the *Chongqing* LQT program is the first experimental program that integrates both China's central land use planning institution and regional transfer of development rights program. Documenting and evaluating such an experimental program directly contribute to the debate on land property rights and the use of TDR in land planning. Second, early studies on TDR programs and/or the Chongqing LQT program mainly involved theoretical and normative analyses, mostly focused on its institutional rationality, legitimacy, and social welfare (Renard, 2007). Others are mainly case studies (Johnston and Madison, 1997; Tan (2019)). There are few empirical studies that quantitatively examine its effects on different development outcomes. By quantitatively examining the effects of the Chongqing LQT program on several development outcomes, our study fills this gap in TDR-related literature.

The rest of the paper is organized as follows. In section 2 we present the policy background and the program design. In sections 3 and 4 we discuss the quantitative method and results. In section 5 we present a series of meso- and micro-level analyses based on satellite image analysis and qualitative interviews. We conclude in section 6 with some policy implications.

2. Background of the Chinese TDR experiment

2.1. Centralized land use planning and urban sprawl

Since the late 1990s, China's central government has adopted a centralized land use planning (CLUP) program (Wang et al., 2010). The primary goal of the CLUP program is to control the speed of urban expansion (to avoid urban sprawl), and to preserve farmland (Rithmire, 2017). Preserving farmland was in fact becoming particularly important after the state council issued the minimum farmland preservation policy in 2006 (State Council, 2006a). The CLUP is mainly implemented through two instruments—the Land Use Master Plan (LUMP) and the Annual Land Use Plan (ALUP)—from the national and even to the township level of government. The LUMP is a rather long-

[3] In China's administrative division classification, a prefecture-level municipality ranks below a province but above a county. Since *Chongqing* is one of the four directly controlled municipalities in China, we use "prefecture" instead of "city" in our study to distinguish this characteristic.

term land use planning guideline (often 15 years, along with China's Five-Year Plan). It specifies the total permitted farmland conversion quotas during the proposed five-year period. It also specifies the amount of the quotas to its sub-level administrative units (Ministry of Natural Resources MRN, 2017). Through this instrument, the land use plan is designed from the national level to the township level.

The ALUP is a short-run, concrete land use quota allocation plan that further breaks down the long-term permitted quotas (five years as mentioned above) into annual land conversion quotas, and further distributes the quotas under its administration (MNR, 2017). In practice, each sub-level government at the beginning of each year has to prepare its ALUP and submit this to its upper-level government for approval. Once it has been approved, the sub-level government will correspondingly allocate these quotas according to its annual land use quota plan (Cai, 2017). The central government strictly regulates and monitors the conversion of agricultural land into non-agricultural land when there are no conversion quotas permitted (State Council, 2006b, 2008).

However, with China's rapid urbanization and migration, such a top-down approach proved to be hardly efficient and too inflexible. Problems arise mainly from two aspects. On the one hand, the LUMP often lacks far-enough foresight that after one to two years, it becomes infeasible because of the fast pace of urbanization, with demand for urban construction land becoming substantially larger than what has been planned for. On the other hand, to maintain economic growth, the sub-level government leaders are often more prone not to comply strictly with their ALUP (Cai, 2012; Xiao, 2014; Schneider and Mertes, 2014). In fact, almost no province has strictly complied with its centralized land use quota plan (Cai, 2012). For instance, the preset total land conversion quotas for Zhejiang province from 1997 to 2010 was 66.7 thousand hectares. However, by the end of 2001, the amount of land conversion quota used had already reached 66.5 thousand hectares. Nearly 70 % of urban prefectures had exceeded its initial planned quota (Wang and Tao, 2009).[4] Another example of urban sprawl is the astonishing growth of the Beijing municipality. A visualization program conducted by NASA (2012) showed that Beijing has been expanded to more than two times its size in 1978.

2.2. Rural construction land: a neglected tumor

The inefficient land use (or land waste) phenomenon is prevalent not only in urban China, but also in its rural areas. With massive migration outflow, rural villages in China have been experiencing fast depopulation, leading to the emerging phenomenon of "hollow villages" (Zhao, 1999; Liu et al., 2010b; Hu et al., 2011). Without a proper exit channel for rural household construction land (e.g., homestead),[5] instead of observing a decrease in rural construction land accompanied by rural depopulation, studies have shown an increasing trend over the past decades (Deng et al., 2015; Kuang et al., 2016; Liu and Li, 2017). For example, statistics from the Ministry of Natural Resources of China [MNR] show that in some prefectures, per capita rural construction land has reached 229 square meters, far exceeding the maximum limit of 150 square meters (People's Daily, 2010). According to the current rural homestead law (Land Administration Law of the People's Republic of China, State Council, 2004; Guaranty Law of the People's Republic of China, State Council, 1995), rural household construction land is prohibited from being commercialized (e.g., selling, mortgage, or bestowal; Wang et al., 2012). Thus, except for transferring their homestead within their rural community, farmers hardly can realize the value of their properties through land markets. For those who have moved to urban cities, their idle rural household construction land (or homestead) cannot provide them any financial benefits but instead, aggravates their economic burden due to the required maintenance (Sun et al., 2011).

2.3. Transfer of development rights: the Chongqing experiment

To preserve limited farmland and improve land use efficiency, the *Chongqing* prefecture government has been experimenting with its first TDR program since 2008—the LQT program. Under the LQT program, a prefecture-scaled land quotas trading market (*Chongqing Country Land Exchange, CCLE*) platform was established at the end of 2008.[6] From the supply side (or *sending areas*), rural villages (particularly those "hollow villages" with a substantial amount of households that have migrated to urban areas), after reclaiming their wasted construction land into qualified farmland,[7] are allowed to register their corresponding quota of land development rights on the CCLE platform for trade within the whole prefecture. Rural households from the sending areas are compensated through the CCLE platform. On the demand side, in the case of regions with higher demand for construction land (often called *receiving areas*), real estate developers (or other legitimate developing entities) could purchase these development rights through the CCLE platform and use them to further purchase the urban land development rights.

To realize this land development rights transfer, the CCLE platform has set a specific procedure for all stakeholders to follow (Chongqing Country Land Exchange, 2008). For instance, for the rural households (or the *sending-area entities*) to register a piece of land development rights, they have to first reclaim the previous constructed areas into a qualified farmland, then report it to the local land development rights office for verification. Once it is verified and acknowledged that the reclaimed farmland meets the requested standards, the corresponding land development rights are registered over to the CCLE platform, and the compensation for rural households is paid. The reclaimed farmland is further packed as a "*ready-to-rent*" farmland for any agri-business entity to rent for the purpose of large-scale farming.

For urban developers, these registered development rights are further auctioned to the public on a monthly basis (Chongqing Country Land Exchange, 2008), such that developers could make purchases through the urban development land auction market (Chongqing Country Land Exchange, 2016a). These development rights can be used to cover the land transaction fee and many other land development project-related costs (Chongqing Country Land Exchange, 2016a). In most cases, the development rights are purchased with a rather low price compared with the land transaction costs or urban land development fee.

This market-based land development rights trading system completely breaks the traditional restrictions of the centralized land use planning scheme (within the whole prefecture) and allows the land conversion quotas to be traded freely (Chongqing Country Land Exchange, 2008). At the national level, its total quota of construction land still complies with the central government's LUMP (Xiao, 2014; Guo and Zhong, 2016), indicating that the whole *Chongqing* prefecture still receives the same amount of permitted land development quota. However, at the prefecture level, the LQT program enables land resources to be relocated, responding to the market demand within the whole prefecture. Thus, the program has automatically matched the surplus in rural construction land with the shortage in urban

[4] Data is collected from the Land Use Master Plan of Zhejiang Province (1997–2010).

[5] Rural construction land includes both rural households' homesteads (many households have more than two pieces of homesteads), and construction land collectively owned by the village. For instance, due to the school merging policy in 2004, many rural primary schools were wasted (Liu et al., 2010a).

[6] The land development rights in *Chongqing* prefecture are called Dipiao (in Chinese). To avoid confusion due to different names, we do not translate it literally, but rather base on its nature.

[7] The prefectural government has issued a set of standards for all the reclaimed land to follow.

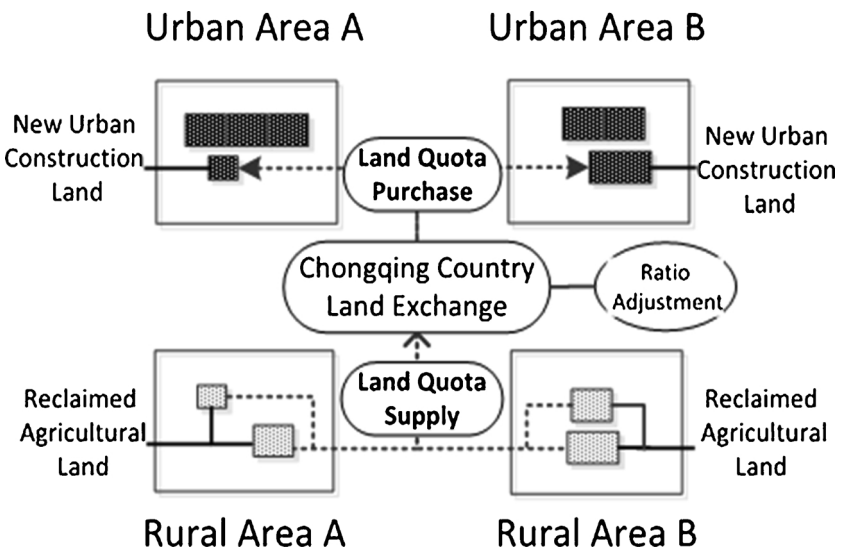


Fig. 1. Chongqing Land Quotas Trading (LQT) program.

construction land among different sub-regions. All the sub-governments' ALUP and LUMP instead serve as general land development guidelines, and as long as the LQT program operates according to its LUMP to the central government, the ALUP and the actual land development are adjusted accordingly.

In terms of preserving farmland, by setting the ratio adjustment between 0 and 1, the prefectural government, through the CCLE platform, can even increase their total farmland (or at least maintain the total amount of farmland when the conversion rate is set at 1). Currently the conversion rate is set at 0.63, indicating that 1 square meter of reclaimed farmland could be converted into 0.63 square meters of land development rights to be traded over at the CCLE platform within the prefecture (Huang, 2015).

The adoption of the LQT program might have played an important role in stimulating economic growth. One direct effect of the LQT program on economic growth relates to improved urban infrastructure development. Specifically, through the LQT program, urban real estate developers are able to access more land development projects around the urban fringe (leading to a significant increase of urban constructed areas), thereby increasing total GDP (Gross Domestic Production). Indirectly, the TDR further affects the local labor market, significantly increasing employment. Through the LQT program, a substantial share of the rural labor force might completely exit from agricultural production and permanently integrate into urban cities and work at secondary and/or tertiary sectors (Fig. 1).

With the introduction of the LQT program in *Chongqing* in 2008, the program has quickly expanded into almost all the 38 sub-districts of the *Chongqing* prefecture by 2011 (CCLE, 2016b). Fig. 2 shows the timeline of the districts' (and counties') participation in the LQT program since 2008. There was particular progress in 2010 and 2011, and by the end of 2011, almost all districts and counties have participated in the LQT program. With regard to the amount of development rights transferred and their prices after 2008, according to the *Chongqing* prefectural CCLE platform, both statistics peaked in 2011 and stabilized afterward. For reference, Fig. 3 presents a reproduction of the statistics from the CCLE platform.

3. Methodology

3.1. The synthetic control method (SCM)

In examining the effect of the LQT program on farmland preservation and economic growth, the fundamental difficulty is the lack of valid counterfactuals that represent a similar socioeconomic situation while not implementing a TDR program over the same period. The initial status and development path of the *Chongqing* prefecture itself was rather unique in many aspects (e.g., geography, economy, and being directly controlled administratively by the central government), which makes it difficult to find a matching, valid counterfactual back in 2008.

To address this problem, we use SCM, which was developed by Abadie and Gardeazabal (2003) and extended in Abadie et al. (2010). Under SCM, a weighted combination of a group of potential control (donor) prefectures (not implementing a similar TDR program) could be used to approximate the most relevant characteristics of the *Chongqing* prefecture before the LQT program was implemented in 2008. Once the counterfactual (the synthetic *Chongqing* prefecture) is estimated and its desired quality has been established, the development (and the trend) of the *Chongqing* prefecture after the LQT program was implemented can be compared with this synthetic prefecture.

Here, we briefly illustrate SCM; a detailed methodological discussion can be found in Abadie and Gardeazabal (2003) and Abadie et al. (2010). Consider a panel of $I_c + 1$ prefectures over T periods, where prefecture i changes its land development policy and adopts the TDR program at time $T_0 < T$, and all the other prefectures of I_c, which represent a sample of potential control prefectures, maintain the same conventional land development policies. The treatment effect for prefecture i at time t, where $t > T_0$, can be defined as follows:

$$\tau_{it} = Y_{it}(1) - Y_{it}(0) \text{ where} t > T_0 \quad (1)$$

where $Y_{it}(1)$ represents the potential outcome of prefecture i at time t when the TDR program was implemented, and $Y_{it}(0)$ is the potential outcome of prefecture i at time t when no TDR program had been carried out. The statistic of interest in this study is the vector of dynamic treatment effects $(\tau_{i,T_0+1}, ..., \tau_{i,T})$ after time t.

To estimate the counterfactual $Y_{it}(0)$, SCM defines W= $(1, w_1, ..., w_{I_c})$ as a $(I_c + 1)$ vector of weights from a pool of potential control prefectures, such that $w_j \geq 0$ and $\sum w_j = 1$.[8] Every value of W is a possible combination of those potential control prefectures (to form a counterfactual for prefecture i, which is *Chongqing* in our case).

Moreover, Y_j and X_j follow an autoregressive model with time-varying coefficients: $Y_{j,t+1} = \alpha_t Y_{j,t} + \beta_{t+1} X_{j,t+1} + \mu_{j,t+1}$, and

[8] In the case of a single treatment unit, the weight for the treated unit (e.g., *Chongqing* prefecture in this case) will always have a weight of 1; the potential control prefectures will yield partial weights and in total weighted as 1 to form the synthetic controlled *Chongqing* prefecture.

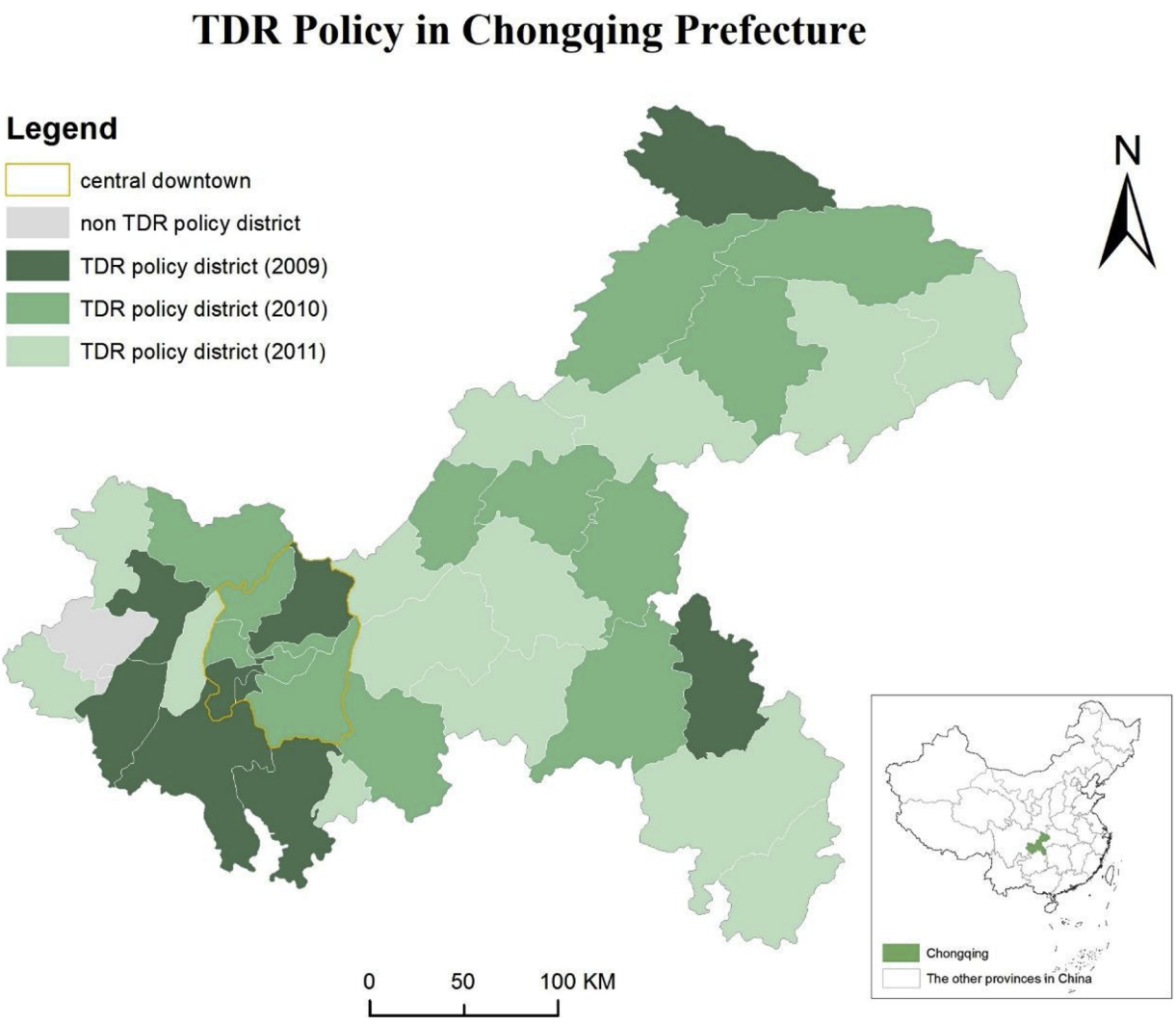


Fig. 2. The development of LQT program in Chongqing from 2009 to 2011.
Note: The data is stored at Resource and Environment Data Cloud Platform of Chinese Academy of Science (CAS).

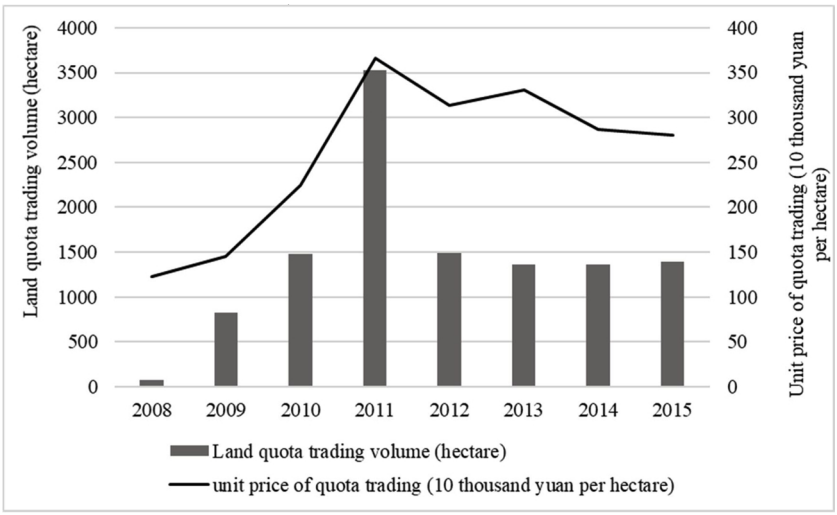


Fig. 3. The development of Chongqing LQT program since 2008.
Note:
(1) Figure is reproduced from Chongqing Country Land Exchange platform.
(2) Data source: online retrieved http://www.ccle.cn/tzgg/tzkb/html-1896/10739.html.
(3) According to the distribution rule, the land quota trading price minus the reclamation cost is shared 85:15 between households and village community. Source: http://www.ccle.cn/zcfg/flfg/tddfxfghgz/html-1861/9030.html

$X_{j,t+1} = \gamma_t Y_{j,t} + \delta_t X_{j,t} + \varepsilon_{j,t+1}$, where both $\mu_{j,t+1}$ and $\varepsilon_{j,t+1}$ have a mean zero conditional on $\mathscr{F}_t = \{Y_{j,s}, X_{j,s}\}_{1 \le j \le N, s \le t}$. Abadie et al. (2010) showed that, as long as one can choose a W^* that satisfies the conditions of (2) and (3):

$$\sum_{J=1}^{I_c} W_j^* Y_j = Y_i \tag{2}$$

$$\sum_{J=1}^{I_c} W_j^* X_j = X_i \tag{3}$$

where X_j is a vector of the relevant observed covariates (not affected by the intervention), then $\hat{\tau}_{it} = Y_{it} - \sum_{J=1}^{I_c} w_j^* Y_{jt}$ is an unbiased estimator of the average treatment effect. In empirical practice, the synthetic control W^* is selected so that condition (3) holds approximately. This is obtained by minimizing the distance (or the root mean square predict error; RMSPE) between the vector of the pretreatment characteristics (X_j) of the potential synthetic control by adjusting the matrix of W. The weights are chosen so that the pretreatment outcomes and the covariates of the synthetic control are, on average, very close to the treated prefectures.

The advantages of using SCM are threefold. First, it is rather transparent, where the weights W^* clearly identify the prefectures that have been used to estimate the counterfactual. This enables identifying inappropriate matches instantly. Second, its application is flexible in that based on the research, the set of potential control prefectures can be restricted to make the underlying comparisons more appropriate. Although the increase of restrictions over potential controls could improve the quality of matches, it decreases the statistic power for further inference; thus, a balance often must be achieved to ensure the quality of estimation and inference. Third, SCM is based on identification assumptions that are much weaker since they allow for the effect of unobservable confounding factors to be time variant. Yet, identification is still based on the assumption that the attribution of a given treatment to one prefecture does not affect the other prefectures, and that there are no spillover effects (stable unit treatment value assumption).

3.2. Case selection and data collection

To examine the effect of the *Chongqing* TDR experiment, we first identified a pool of feasible control prefectures with similar geographic and socioeconomic development background. Specifically, we first selected five provinces (i.e., *Sichuan, Hunan, Hubei, Jiangxi,* and *Guizhou*) around the *Chongqing* prefecture to ensure similar geographic characteristics. Except for *Jiangxi* province, the four other provinces are all located in the southwest of China, where farmland is rather scarce and urbanization has been progressing dramatically in recent years (Chen et al., 2018).[9] We collected land, urban construction areas, per capita GDP data, and many other relevant socioeconomic development statistics of 57 prefectures within these five provinces.[10] Table 2 shows all potential control prefectures included in our study.

We constructed our datasets by combining multiple sources of official data from 2001 to 2014. For instance, the regional economic development statistics (e.g., population, GDP, and per capita GDP) and land use information were mainly from the China City Statistical Yearbook (National Bureau of Statistics of China, 2015) and the *Chongqing* Statistics Yearbook (Chongqing Statistics Bureau, 2002). Data on *Chongqing* land quotas trading came from a field survey at *Chongqing* administration of land, resources, and housing. To make the data more unified, the land use data was calculated based on the national land classification (transition period is applicable), and the data from the second national land survey after 2009 were converted into a uniform standard. All these variables, their definition, and sources are presented in Table 1.

We examined the effect of TDR primarily on four outcomes. First is its effect on prefecture-level farmland preservation (measured as per capita farmland, Table 1, row 1) and second is its effect on urban development (measured as per capita urban constructed area, Table 1, row 2). We focused on these two outcomes because they are directly related to the implementation of the TDR program. Third, we further examined if the *Chongqing* TDR experiment has improved local labor market performance (measured as a percentage of the formal employed population[11], Table 1, row 3). Last, we examined if it has potential effects on local economic growth, measured by per capita GDP.

To create a comparable synthetic Chongqing prefecture, the vector of covariates X_j' was selected following two primary principles. First, the selected pre-treatment covariates have to be exogenous, meaning that selected covariates were not affected by the treatment (in our case the TDR program), and there were also no "anticipation" effects (Abadie et al., 2015). Second, the covariates have to be strongly correlated with the examined outcomes to yield high predictive power. For example, to examine the effect of TDR on per capita farmland, we selected the following covariates: per capita land endowment, percentage of added forest of the total prefectural land, per capita GDP, percentage of first sector employment, percentage of first GDP out of the total GDP, per capita urban constructed areas, percentage of second and third sectors employment, and the log form of per capita fiscal income. We also included the pretreatment percentage of farmland at year 2003 and 2007 (Table 3, Column 1) to improve the quality of the match. We present all detailed use of covariates for other synthetic experiments in Table 3, and its balanced check against the synthetic *Chongqing* prefecture.

3.3. Inferences

As Abadie et al., 2010 suggested placebo experiments based on permutation techniques can be implemented to make inferences. Following their approach, we implemented cross-sectional placebo tests. Specifically, we sequentially applied the synthetic control algorithm to every prefecture in the pool of 57 potential control prefectures and compared the placebo with the baseline results. For each potential control prefecture I_c, we estimated the dynamic treatment effects, including the actual treated prefecture (*Chongqing* prefecture) in the donor pool using SCM. We then compared these (placebo) effects with those estimated for the actual treated (*Chongqing*) prefecture to assess whether the baseline estimates for the treated prefecture are large relative to the effects from prefectures chosen at random. If the placebo studies create gaps of magnitude equivalent to (unusually small relative to) the one estimated for the *Chongqing* prefecture, this means that our analysis does not provide (provides) significant evidence of a positive effect of TDR over the outcome we study. In practice, placebo effects might be quite large due to poorly matched qualities in the pretreatment period (indicated by a high RMSPE value). To prevent this from happening, we may restrict the set of comparison controls by including

[9] Although *Jiangxi* province is located in the central south of China, it, in fact, has quite similar geographic characteristics, and urbanization in *Jiangxi* province is progressing massively. Therefore, in the analysis we have further added prefectures from *Jiangxi* province to enlarge our sample size.

[10] Since *Chongqing* is a rather unique prefecture in the southwest of China, with its large population and economic development, and it is also a municipality directly under the central government administration, we restricted the potential control prefectures to at least a prefectural-level municipality.

[11] We used the formal employed population instead of the off-farm employed labor force as we were unable to collect all sampled prefectures' labor statistics. Moreover, with the collected prefecture data, we found that the quality is rather poor in terms of consistency. Assuming that in a short period of time, the percentage of labor force within each prefecture is stable, we used the population as the denominator and the number of formal employed labor force as the numerator, defined as formal employed population.

Table 1
Data description and clarifications.

Variable name	Description	Source
Per capita farmland (m^2 per capita)	Total farmland divided by prefectural total population	China City Statistical Yearbook & Statistical Yearbook of five provinces
Per capita urban constructed areas (m^2 per capita)	Total urban constructed (or built-up) area divided by prefectural total population Urban constructed area measures the non-agricultural area that has been developed and has basic municipal infrastructure within a municipal administrative area.	China City Statistical Yearbook
Percentage of the formal employed population	Total employed population in all three sectors divided by prefectural total population	China City Statistical Yearbook
Percentage of 2nd and 3rd sectors employment	Total employed population of the second and third sectors divided by prefectural total employed population	China City Statistical Yearbook
Percentage of 1st sector employment	Total employed population of the first sector divided by prefectural total employed population	China City Statistical Yearbook
Per capita gross domestic production (GDP, yuan per capita)	Prefectural total gross domestic production (GDP) divided by prefectural total population	China City Statistical Yearbook & Statistical Yearbook of five provinces
Per capita land endowment (m^2 per capita)	Prefectural total land area divided by prefectural total population	China City Statistical Yearbook
Percentage of added forest of the total prefectural land	Percent of newly added forest area divided by prefectural total land area	China Forestry Statistical Yearbook
Prefectural total population	Prefectural annual population (in 10 thousand people)	Statistical Yearbook of five provinces
Percentage of the 1st, 2nd and 3rd sectors GDP in total GDP	Agricultural, secondary, and tertiary industries' GDP divided by prefectural total GDP respectively	China City Statistical Yearbook
Per capita fiscal income (yuan per capita)	Government general budgetary revenue divided by prefectural total population	Statistical Yearbook of five provinces
Per capita electricity consumption (watt per capita)	Annual electricity consumption divided by prefectural total population	China City Statistical Yearbook
Per capita road length (m per capita)	Highway length divided by prefectural total population	China Statistical Yearbook for Regional Economy

only those prefectures that match well (by restricting the RMSPE value to a certain low level).

4. Quantitative results

4.1. Quality of synthetic Chongqing prefecture

In the following section, we first present the weights of each SCM experiment to evaluate the quality of the synthetic *Chongqing* prefecture. Table 2 displays the weights of each control prefecture in the synthetic *Chongqing* prefecture. For example, with regard to farmland preservation, weights reported in Table 2 indicate that the best synthetic *Chongqing* prefecture prior to the LQT program can be reproduced by a combination of Chengdu (0.241), Guang'an (0.010), Suining (0.090), Ya'an (0.106), Anshun (0.531), and Guiyang prefectures (0.022; Table 2, Column 1). All the remaining prefectures were assigned zero weights. Experiments further applied regarding per capita urban constructed areas, percentage of the formal employed population, and per capita GDP were all assigned with different weights accordingly to create the synthetic *Chongqing* prefecture (Table 2, Column 2–4).

The balance of the pre-treatment covariates between *Chongqing* prefecture and the synthetic *Chongqing* prefecture are presented in Table 3 separately for each experiment. For example, we listed the values for the *Chongqing* prefecture over each covariate in the first column (Table 3, Column 1). In the second column, we presented the mean values of each covariate for all the control prefectures before running SCM. In column 3, we presented the covariates' mean values for the synthetic *Chongqing* prefecture after running SCM (Table 3, Columns 2 and 3). After running SCM, we find that the differences among all covariates decreased significantly and the overall RMSPE was rather small (about 9.825 square meters in terms of the per capita farmland; Table 3, Panel 1, Column 3). We further examined the balance achieved among all other three experiments. The same results were observed from the balance check—the differences among all covariates were significantly reduced, and the calculated RMSPEs were quite small (Table 3, Panels 2, 3 and 4).

In the following sections we further graphically show the quality of the pre-treatment match between the treated (*Chongqing*) prefecture and the synthetic *Chongqing* prefecture. This graphic comparison provides a more vivid image of the pre-treatment synthetic quality evaluation.

4.2. The effect of the TDR program on farmland preservation

In Fig. 4a, prior to the TDR program in 2008, we can observe a significant decline of the per capita farmland for both the *Chongqing* (as indicated by the solid line, Fig. 4a) and synthetic *Chongqing* prefectures (as indicated by the dash line). The fast decline of farmland during 2001–2003 could be driven by a combination of both rapid urbanization and China's '*grain-to-green*' project that started in 2001.[12] However, the decline of farmland from 2003 to 2008 can be mainly attributed to rapid urban expansion (Fig. 4a). After 2003 the declining trend of per capita farmland between the *Chongqing* and synthetic *Chongqing* prefectures are much closer, indicating that the previous (2001–2003) '*grain-to-green*' program by the government has created a rather unpredicted error when applying SCM.

The post-TDR period after 2008 shows the effect of the TDR program on farmland preservation. Comparing the *Chongqing* prefecture (solid line) with the synthetic *Chongqing* prefecture (dash line), we can see that they developed quite different paths. The decline of per capita farmland in the *Chongqing* prefecture has slowed-down. Meanwhile, the synthetic *Chongqing* continued its fast-declining trend until 2014. The decrease in per capita farmland was rather high from 2008 until 2010, continuing to decrease after 2010, albeit at a slower pace. This result indicates that the implementation of the TDR program has indeed slowed-down the decreasing trend of per capita farmland, and the effect was quite substantial in the long run.

To further quantify its effect on farmland preservation, in Fig. 4b we present the gap between the *Chongqing* prefecture and the synthetic *Chongqing* prefecture, both before and after the TDR program. As we can see from the figure, prior to 2008 (pre-TDR period), the gap was minimized to around zero during 2003–2007.[13] After the TDR program started operating in 2008, it has preserved more than 30 square meters

[12] In fact, the significant decrease of farmland due to the government's '*grain-to-green*' program has also affected the quality of our pre-treatment match. It is very hard to collect the actual prefecture-level data on how much farmland has been returned to the forest. This program, implemented in different provinces, was stretched over different periods; although in general, most provinces finished this '*grain-to-green*' program around 2005.

[13] A significant peak observed during 2001 to 2003 might be due to the progressive "*grain-to-green*" program during that period, as explained above.

Table 2
Potential control prefecture weights used in generating the synthetic *Chongqing* prefecture.

		Weights used for each potential control prefecture to generate the synthetic *Chongqing* prefecture			
Outcomes	*Measurements*	On farmland preservation: *Per capita farmland (m^2 per capita)*	On urban development: *Per capita urban constructed areas (m^2 per capita)*	On labor market performance: *Percentage of the formal employed population*	On economic growth: *Per capita GDP (yuan per capita)*
Provinces	Prefectures	(1)	(2)	(3)	(4)
Sichuan	Bazhong	0	0	0	0
(17)	Chengdu	0.241	0	0.001	0.002
	Dazhou	0	0	0	0
	Deyang	0	0	0.002	0.003
	Guang'an	0.010	0	0.001	0.001
	Guangyuan	0	0.001	0	0.001
	Leshan	0	0	0.001	0.001
	Luzhou	0	0	0.001	0.002
	Meishan	0	0.085	0.001	0.001
	Mianyang	0	0.24	0.001	0.003
	Nanchong	0	0.135	0	0
	Neijiang	0	0	0.271	0.004
	Suining	0.090	0	0.017	0.003
	Ya'an	0.106	0	0	0.001
	Yibin	0	0.001	0.001	0.098
	Ziyang	0	0	0	0.001
	Zigong	0	0	0.001	0.004
Guizhou	Anshun	0.531	0	0.001	0
(4)	Guiyang	0.022	0	0	0.005
	Liupanshui	0	0	0.233	0.053
	Zunyi	0	0	0.023	0.001
Hubei	Ezhou	0	0	0.001	0.019
(12)	Huanggang	0	0	0.002	0.001
	Huangshi	0	0.022	0.098	0.001
	Jingmen	0	0	0.002	0.001
	Jingzhou	0	0	0	0.003
	Shiyan	0	0	0.002	0.126
	Suizhou	0	0.199	0.001	0.001
	Wuhan	0	0	0	0.001
	Xianning	0	0	0.001	0.001
	Xiangyang	0	0	0	0.001
	Xiaogan	0	0	0.002	0.001
	Yichang	0	0	0.066	0.001
Hunan	Changde	0	0	0.005	0.002
(13)	Chenzhou	0	0	0.001	0.003
	Hengyang	0	0	0.001	0.006
	Huaihua	0	0	0.001	0.001
	Loudi	0	0	0.001	0.402
	Shaoyang	0	0	0.001	0.001
	Xiangtan	0	0	0.001	0.232
	Yiyang	0	0	0	0.001
	Yongzhou	0	0	0.001	0.001
	Yueyang	0	0	0.003	0
	Zhangjiajie	0	0	0.002	0.001
	Changsha	0	0	0.001	0.002
	Zhuzhou	0	0	0.001	0.003
Jiangxi	Fuzhou	0	0	0	0
(11)	Ganzhou	0	0	0.001	0.001
	Ji'an	0	0	0	0
	Jingdezhen	0	0	0.001	0.001
	Jiujiang	0	0.241	0	0.001
	Nanchang	0	0	0	0.001
	Pingxiang	0	0	0.245	0.002
	Shangrao	0	0	0.001	0
	Xinyu	0	0.078	0	0
	Yichun	0	0	0.001	0.001
	Yingtan	0	0	0	0
Total		57	57	57	57
Matched prefectures		6	9	40	47
Total weights		1.000	1.000	1.000	1.000

of farmland per capita in *Chongqing* by year 2010. From 2010 to 2014, the preservation of farmland increased further (almost up to 50 square meters per capita; Fig. 4b). This does not simply mean that the TDR program in the *Chongqing* prefecture has increased its total farmland by such a large amount. Rather, this means that considering other similar prefectures without a TDR program, the TDR program has saved (through reclaiming procedures) a large amount of farmland per capita.

To test whether our findings were merely driven by chance, we ran the placebo test as we have explained in section 3.3. Fig. 4c plots the 57 experiments (dash lines) relative to the *Chongqing* TDR program (placebo test). The lines in Fig. 4c denote the effects of the TDR program on the farmland preservation associated with each of the 57 experiments of

Table 3
Pre-treatment fit and balance of covariates in the SCM.

	Chongqing prefecture (1)	Average of all donor prefectures (2)	Synthetic Chongqing prefecture (3)
Panel 1: Effect of TDR on farmland preservation			
Per capita land endowment (m^2 per capita)	2611.831	3,086.648	3,443.562
Percentage of added forest of the total prefectural land	0.010	0.009	0.010
GDP per capita (yuan per capita)	7827.445	13,909.611	8,477.249
Percentage of 1st sector employment	0.011	0.032	0.030
Percentage of 1st GDP out of the total GDP	0.148	0.185	0.202
Per capita urban constructed areas (m^2 per capita)	16.643	16.999	16.149
Percentage of 2nd and 3rd sectors employment	0.989	0.968	0.970
Log of per capita fiscal income	14.575	13.199	12.430
Per capita farmland at time T_{2007}	748.242	575.315	748.465
Per capita farmland at time T_{2003}	878.121	583.418	878.164
RMSPE			9.825
Panel 2: Effect of TDR on urban development			
GDP per capita (yuan per capita)	7827.445	13,909.611	7,897.356
Percentage of 2nd and 3rd industries' GDP	0.852	0.815	0.780
Percentage of 2nd and 3rd sectors employment	0.989	0.968	0.936
Per capita electricity consumption (watt per capita)	706.907	804.918	561.843
Per capita fiscal income (yuan per capita)	717.687	1,971.123	721.210
Per capita road length (meter per capita)	1.651	2.391	1.673
Per capita urban constructed area T_{2007}	20.616	12.062	20.634
Per capita urban constructed area T_{2005}	16.731	15.713	16.765
Per capita urban constructed area T_{2001}	10.617	14.093	10.654
RMSPE			0.259
Panel 3: Effect of TDR on labor market performance			
GDP per capita (yuan per capita)	7827.445	13,909.611	7,750.847
Percentage of 2nd and 3rd industries' GDP	0.852	0.815	0.848
Per capita road length (meter per capita)	1.651	2.391	1.648
Per capita electricity consumption (watt per capita)	706.907	804.918	705.291
Per capita fiscal income (yuan per capita)	717.687	1,971.123	754.532
Percentage of the formal employed population T_{2007}	0.071	0.078	0.071
Percentage of the formal employed population T_{2001}	0.066	0.076	0.066
RMSPE			0.001
Panel 4: Effect of TDR on economic growth			
Percentage of 2nd and 3rd sectors employment	0.989	0.968	0.992
Per capita electricity consumption (watt per capita)	706.907	804.918	706.482
Per capita road length (meter per capita)	1.651	2.391	1.657
Per capita fiscal income (yuan per capita)	717.687	1,971.123	718.900
GDP per capita at T_{2007}	10,726.470	11,640.613	10,750.150
GDP per capita at T_{2005}	7,631.925	8,180.453	7,648.483
GDP per capita at T_{2001}	5,613.534	5,886.785	5,626.297
RMSPE			38.922

Note: (1) RMSPE stands for rooted mean square prediction error. The smaller the RMSPE, the better the fit of the synthetic *Chongqing* to the actual *Chongqing* prefecture.
(2) The comparisons over different panels were mean value comparisons over 2001–2008 before implementation of the LQT program.

the test (same as we have observed in Fig. 4b). In Fig. 4d we further restricted the RMSPE (to smaller than 15 square meters) to remove the poor matches from the inference and yield a better view of the effect of the actual *Chongqing* TDR program over the other placebo tests. Both Fig. 4c and d clearly show that the estimated effect of the *Chongqing* TDR program is notably larger relative to the distribution of the placebo effects from the donor pool prefectures during the post-TDR period.

4.3. The effect of the TDR program on per capita urban constructed areas

We further examined the effect of the TDR program on urban development, specifically on per capita urban constructed areas before and after the TDR program. Fig. 5a shows the trend of per capita urban constructed areas (in square meters), both before and after the TDR program. We can see from the figure that both the *Chongqing* and synthetic *Chongqing* prefectures were experiencing a steady growth over the period 2001–2008, and both (solid and dash) lines are rather close. The measured RMSPE was rather small (Table 3, Panel 2, Column 3). Fig. 5b shows that the differences during the pre-treatment period between the *Chongqing* and the synthetic *Chongqing* prefectures were almost zero.

The effect of the TDR program on per capita urban constructed areas did not significantly increase in 2009. Rather, from 2010 a significant divergence between the *Chongqing* and the synthetic *Chongqing* prefectures can be observed (Fig. 5a). We can see that after 2010, the per capita urban constructed area was increasing significantly in the *Chongqing* prefecture relative to the synthetic *Chongqing* prefecture. Fig. 5b shows the quantified differences after 2008. By 2010, the per capita urban constructed area in the *Chongqing* prefecture was about 5 square meters higher than the synthetic *Chongqing* prefecture. However, by 2014, this has increased to almost 15 square meters (Fig. 5b). This is intuitively understandable since most of the development rights were first registered in the platform in 2008, and it often took about one to two years to complete the actual development project. We expect that the per capita urban constructed areas might have further increased after 2014 since more land development rights had been generated in advance.

In the placebo test, we further made comparisons with all 57 potential control prefectures, and the results are shown in Fig. 5c (and Fig. 5d after we set the RMSPE below 10 square meters), which are rather robust. Overall, from our analysis, we find that the TDR program has significantly alleviated land pressure in urban sectors and simultaneously preserved farmland for agricultural production.

While the above analysis focuses on the direct effects of the TDR program on land management, we might also expect some indirect but important spillover effects on *non-land-based* development indicators.

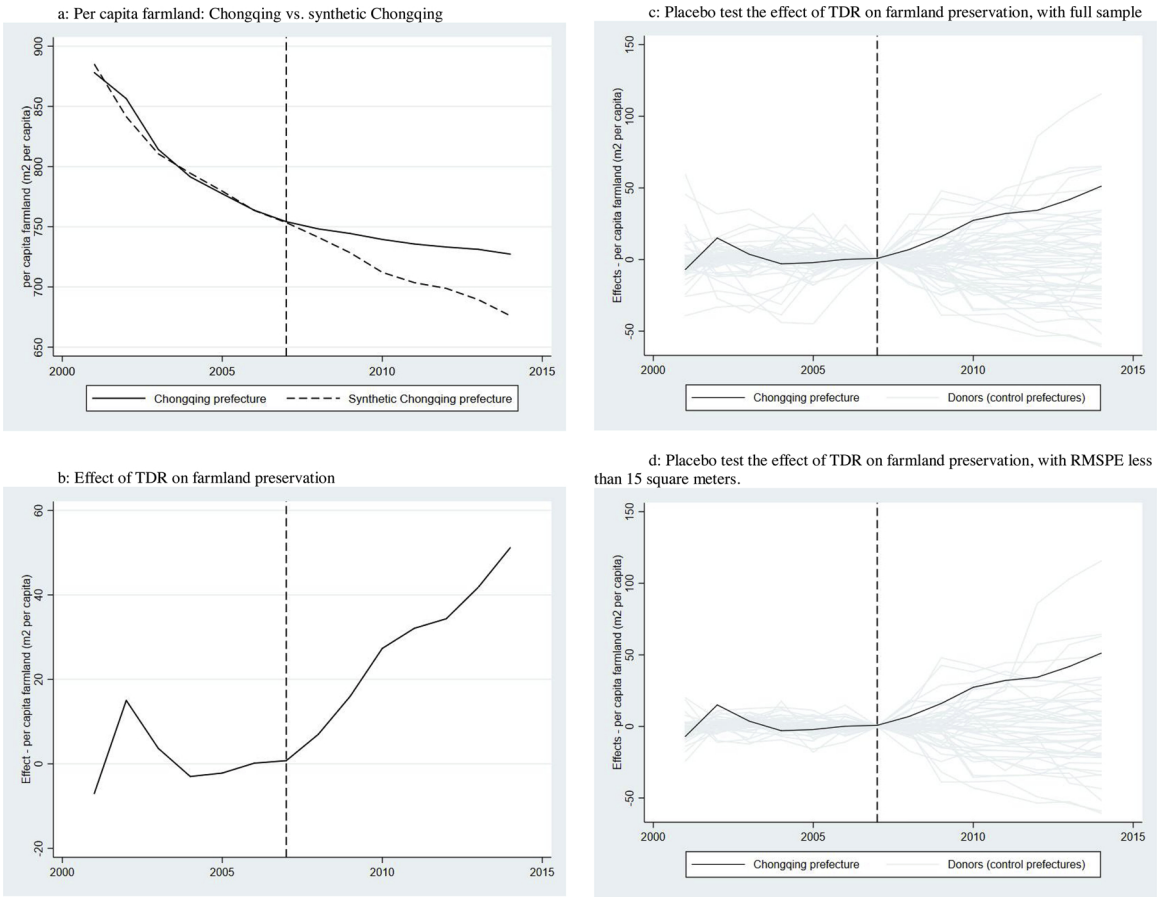


Fig. 4. a. Per capita farmland: Chongqing vs. synthetic Chongqing, b. Effect of TDR on farmland preservation.
Note: The line is measured as the difference between Chongqing and the synthetic Chongqing prefecture. c) Placebo test the effect of TDR on farmland preservation, with full sample. d. Placebo test the effect of TDR on farmland preservation, with RMSPE less than 15 square meters.
Note: RMSPE stands for root mean square prediction error.

Specifically, we have observed some potential effect of the TDR on labor market performance, particularly in terms of improving employment. For instance, participating in the TDR program provides rural residences (those who have the potential to integrate into urban formal sectors) a well-compensated channel to leave both their farmland and rural homestead and permanently integrate into the urban formal sectors. Meanwhile, urban areas could gain a substantial amount of development rights through the TDR program, which might significantly lower the urban housing price and ease the difficulties of rural migrants to integrate into *Chongqing* urban livelihood. All these spillover effects might contribute to the growth of the formal employed population. Besides, lower housing prices for local and rural migrants and more development rights for urban construction might also attract other business investments and thereby form a higher level of industry conglomeration and improve urban infrastructure (e.g., more high-way, railroads, airports and so on). Therefore, in the following sections we further examine if the TDR program has some potential indirect effects on the labor market performance and ultimately, economic growth (measured as per capita GDP).

4.4. The effect of the TDR program on labor market performance

Our empirical results show that prior to the implementation of the TDR program in *Chongqing*, the growth of the formal employed population in *Chongqing* and the synthetic *Chongqing* prefecture were almost identical—around 6%–7% of population were formally employed (0.06 ~ 0.07, Fig. 6a). In Fig. 6b we find that the pre-treatment difference between the *Chongqing* and synthetic *Chongqing* prefectures was almost zero up to 2008. However, after 2010 there was a significant jump in the formal employed population of the *Chongqing* prefecture (Figs. 6a and b).

The placebo tests show the same results. In the long run we see a substantial increase in the formal employed population of the *Chongqing* prefecture relative to the synthetic *Chongqing* prefecture. The results are rather robust, and we can see in Fig. 6c that almost no other prefecture presents such a high increase. However, we need to be careful in interpreting this result. First, as we have noticed from Fig. 6a, the rapid increase of the percentage of the formal employed population happened after 2010, almost two years after the TDR program was implemented. Second, even though the TDR program potentially increased the formal employed population, we might overestimate its actual effect due to the household registration policy. In fact, in our field study we learned that a substantial share of rural households, after participating in the TDR program and reclaiming their homestead, had changed their household registration type in the local government to urban residence (or urban Hukou). With the change of Hukou type, migrants could be immediately reclassified as formal employed labor, which was not the case before the TDR implementation.

4.5. The effect of the TDR program on per capita GDP

Lastly, we examined the effect of the TDR program on promoting economic growth (measured by per capita GDP). Fig. 7a shows the trends in per capita GDP in the *Chongqing* and synthetic *Chongqing* prefectures. The growth paths of per capita GDP over the period 2001–2008 for both the *Chongqing* and synthetic *Chongqing* prefectures were almost identical, and the difference (shown in Fig. 7b) was almost zero—only about 100 yuan difference relative to the average 12 thousand yuan per capita GDP

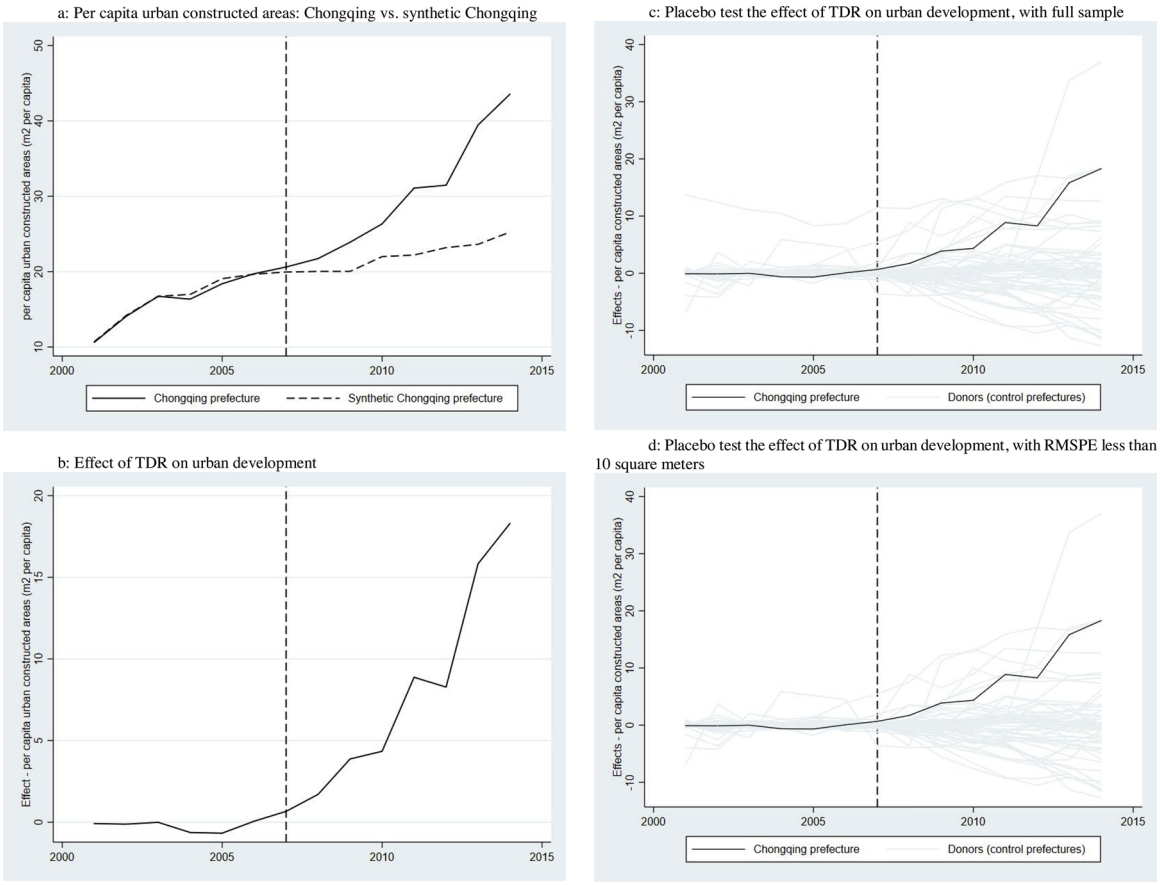


Fig. 5. a. Per capita urban constructed areas: Chongqing vs. synthetic Chongqing. b. Effect of TDR on urban development.
Note: The line is measured as the difference between Chongqing and the synthetic Chongqing prefecture. c. Placebo test the effect of TDR on urban development, with full sample. d. Placebo test the effect of TDR on urban development, with RMSPE less than 10 square meters.
Note: RMSPE stands for root mean square prediction error.

prior to the TDR program's implementation in 2008. After 2008, we observe rapid growth of per capita GDP for both the *Chongqing* and synthetic *Chongqing* prefectures. However, the *Chongqing* prefecture's per capita GDP growth rate was slightly higher than that of the synthetic *Chongqing* prefecture after 2008. Looking into the differences in Fig. 7b, we can see that by 2010 the per capita GDP of the *Chongqing* prefecture was about 500 yuan higher than that of the synthetic *Chongqing* prefecture, which continued growing at a faster pace, indicating possibly even a larger difference beyond the period covered in this study. In fact, by 2014, the difference between the *Chongqing* and synthetic *Chongqing* prefectures' per capita GDP was about 1.4 thousand yuan. The placebo test (Fig. 7c and d) shows a rather robust and stable result, meaning that the implementation of the TDR program indeed slightly affected local economic growth.

5. Qualitative results

Although we have argued the potential mechanisms of how the TDR program might have contributed to economic growth, the above quantitative analysis might be insufficient for drawing a strong conclusion, as there might be many other factors that helped stimulate economic growth during the same period. Thus, a micro-level study of the effects of the TDR program could be essential to draw a more rigorous conclusion. However, conducting a micro-level household study on the TDR program might also present several fundamental difficulties. First, as a prefecture-level land institutional program, the TDR program not only has impact on the rural residences' livelihood in remote areas (as a development rights *sending area*), but also on the urban development sectors (as a *receiving area;* e.g., lower house prices and more business investments) due to greater supply of urban construction land. In urban areas, such effects further interact with other development policies (e.g., investment and tax reduction for small and medium-sized businesses), which hardly can be examined with micro-level household level data. Second, the effect of the TDR program can be extended over a long period. Almost no such micro-level household data have been collected for such a long period. Third, even if there are micro-level household data for the *Chongqing* prefecture, to build a valid counterfactual of the *Chongqing* prefecture, similar long-period datasets from other (a large pool of) prefectures before and after the TDR program's implementation are still needed, which hardly can be realized under current program settings.

However, having these limitations does not mean that the issues should not be examined at the micro-level. We have conducted some qualitative interviews to further examine the indirect effect of TDR on economic growth. In the following section, we provide some meso- and micro-level household evidence from our qualitative field studies.

First, using existing satellite image datasets collected by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (CAS, 2016), we first show graphically how the TDR program affected farmland preservation and urban expansion.[14] Fig. 8a shows a satellite image from one of *Chongqing*'s counties (Nanchuan County) from 2005 to2015. Nanchuan County is

[14] The geographic data were collected by the Institute of Geographic Sciences and Natural Resources Research at the Chinese Academy of Sciences (CAS) periodically from the early 1990s until 2015 every five years. The data are stored at the Resource and Environment Data Cloud Platform of the CAS, and it is available for public use.

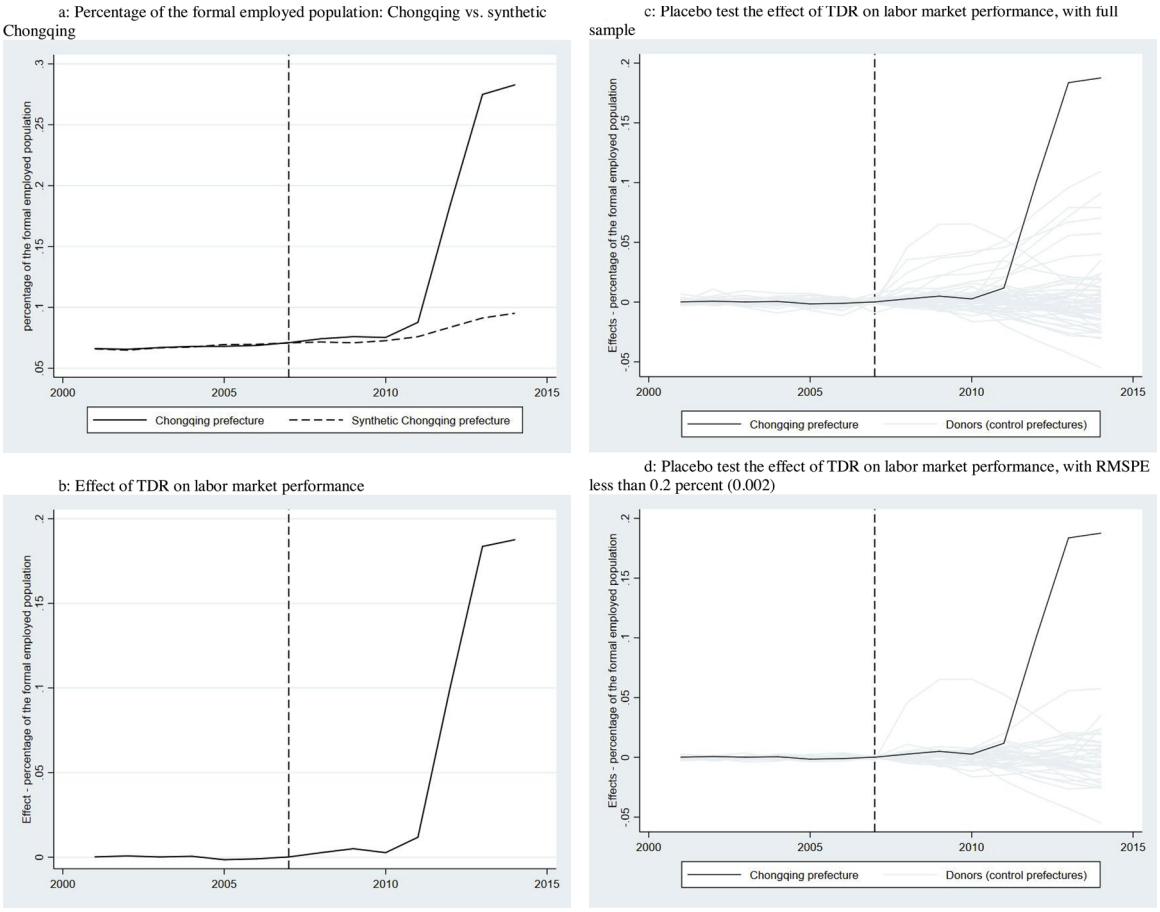


Fig. 6. a. Percentage of the formal employed population: Chongqing vs. synthetic Chongqing. b. Effect of TDR on labor market performance.
Note: The line is measured as the difference between Chongqing and the synthetic Chongqing prefecture. c. Placebo test the effect of TDR on labor market performance, with full sample. d. Placebo test the effect of TDR on labor market performance, with RMSPE less than 0.2 percent (0.002).
Note: RMSPE stands for root mean square prediction error.

located in the southwest of the *Chongqing* prefecture, per capita GDP ranked 28 among its 38 counties (*Chongqing* Statistic Yearbook, 2016). Comparing the whole region's geographic image from 2005 to 2015 we can see that the central urban constructed areas (indicated by the dark blue areas) have increased slightly. However, the scattered remote rural villages (as indicated by the red plotted areas) have decreased or completely disappeared from the image (Fig. 8a). We further zoomed into one township of the Nanchuan County (Nancheng Township in Fig. 8b), revealing more detailed information. We find that the urban constructed areas have increased substantially in this township (a substantial increase of dark blue areas at the upper-north part of the township). Meanwhile, some of the dark red plots (rural villages) have changed into farmland (dark yellow). The constructed areas in the township have become greatly concentrated in 2015, relative to how it was 10 years ago.

Second, we further conducted a small-scale field survey (a total of 281 households over 23 villages) in 2014 with households that participated in the TDR program since 2009. We found that all interviewed households have at least one family member who already lived and worked in *Chongqing* city or their county seat. More than 96 % of these migrants reported that they will not move back to live in their homestead in the rural village. As shown in Fig. 9, a substantial share of households participated in the LQT program between 2010 and 2012 in surveyed villages. The compensation for the reclamation of the homestead was about 168 thousand yuan per mu, and this compensation was further allocated between household and village community following a ratio of 85:15.[15] On average, households received about 143 thousand yuan per mu as compensation for their homestead reclamation (Fig. 10), and the compensation for the village community was about 25 thousand yuan per mu.

In terms of off-farm employment, the implementation of the LQT program has greatly eased rural migrants' worry about their homestead and promoted migration of the whole family instead of just individuals. For instance, reports from household heads who have been working in the urban cities show that either they have found temporary employment or they were looking for better employment.

> "*We have reclaimed our rural houses because both of my sons are working in Chongqing, and they have already bought their own houses. We are too old to do farming, but my son found me a job as a storage keeper, which is not very complicated. My wife and I have decided to move in with our elder son." (senior TDR participants, age 66, Sunjiapo village).*
>
> "*I have been working in Chongqing for quite a long time, but I did not have enough money to pay the initial payment for a house. It is about time for my kid to go to junior high school; we want him to go to a better-quality junior high school, so we joined the LQT program when the village*

[15] The ratio was temporarily set at 85:15 between households and village committee as a community administrative cost. The village as an administrative unit still exists; however, rural households might scatter out after their homestead is reclaimed. The policy was retrieved from http://www.ccle.cn/zcfg/flfg/tddfxfghgz/html-1861/9030.html.

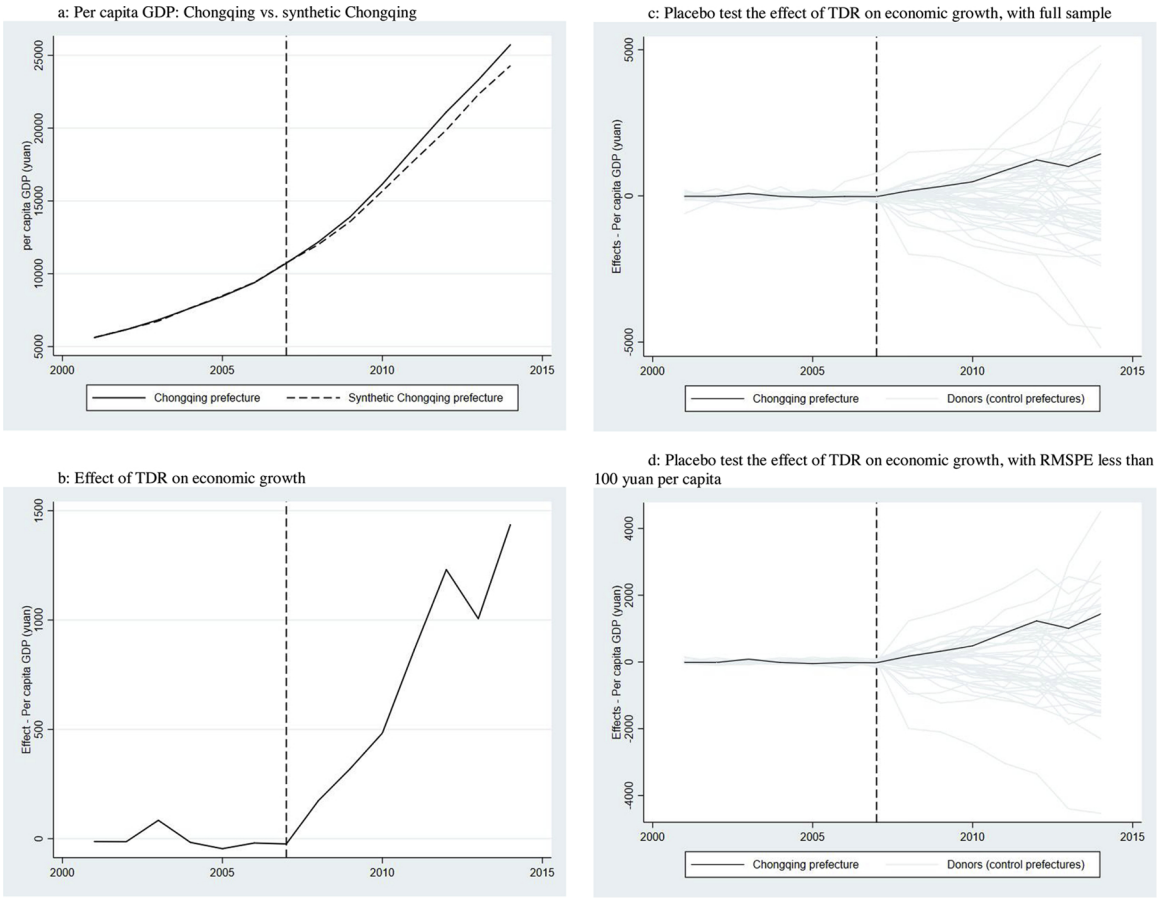


Fig. 7. a. Per capita GDP: Chongqing vs. synthetic Chongqing. b. Effect of TDR on economic growth.
Note: The line is measured as the difference between Chongqing and the synthetic Chongqing prefecture. c. Placebo test the effect of TDR on economic growth, with full sample. d. Placebo test the effect of TDR on economic growth, with RMSPE less than 100 yuan per capita.
Note: RMSPE stands for root mean square prediction error.

leader informed us about this policy, and we got our old houses in the village reclaimed. In fact, I have two pieces of construction land under my name because of my father. We received compensation and now, we are planning to buy an apartment near my work." (TDR participants, age 38, Maxuan village).

From our interviews with local government officials, we find that the main disputes about the LQT program in terms of implementation concerns land with unclear titles. For instance, a rural primary school might have been sold to someone many years ago during a previous village committee. Current village cadres then might want to reclaim and trade it for development rights. Other disputes might also happen among households who have an unclear claim on a certain piece of construction land.

"*Back in 2004 after the primary school was merged to the neighboring village, this place (the village primary school) had been wasted for quite a long time. In 2007 I signed a contract with the village committee to rent this place for eight years, and I used it as a small-scale chicken farm. Now, it has not even been three years later, and they want me to move out." (rural farmer who was in a dispute about the LQT program, age 45, Shipan village)*.

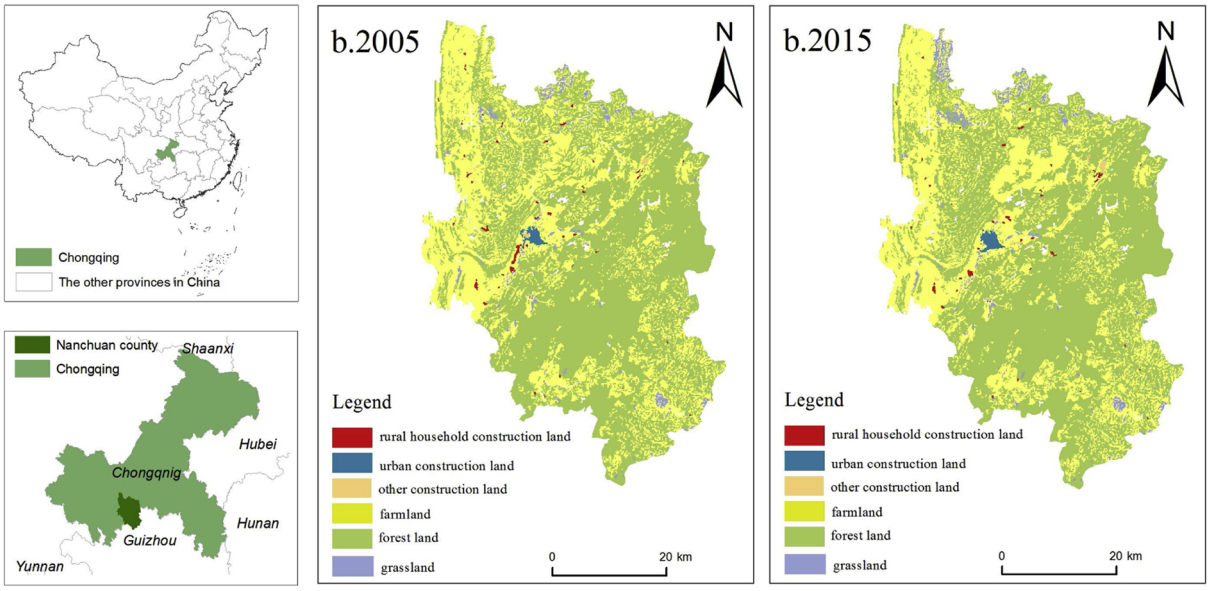
However, despite these disputes about the LQT program, it was generally acknowledged and welcomed by local villagers, particularly among those who have already integrated their life and work in the urban cities. They have quite a strong incentive to marketize their piece of rural construction land and get compensated.

6. Conclusion and policy implication

Rapid urbanization in many developing countries has been intensifying the demand for urban construction land. How to manage such a growing demand and simultaneously maintain proper amount of farmland for agricultural production has become an urgent policy dilemma. Implementing programs for the transfer of development rights to optimize land use efficiency has been observed in many developed economies. However, implementing such a program in a developing country presents many challenges. In our study, we examined an experimental TDR program—the LQT program—in *Chongqing* to show the impact of such a market-oriented land use instrument on farmland preservation, urbanization, and economic development.

We find that integrating the TDR program into China's centralized land use planning can significantly improve land use efficiency and potentially promote economic growth. We find that at the prefecture level, the adoption of the TDR program has slowed the decline of farmland significantly, and this effect has continued for quite some time. Correspondingly, in the urban regions, adoption of the TDR program has enabled urban (or real estate) developers to receive more development rights, which has further increased urban construction areas. Moreover, adoption of the TDR program might have also significantly alleviated rural labor's and migrants' concern about their remote rural homestead permanently, further improving their labor market performance (i.e., increased formal employed population). However, this result might still need more rigorous and stronger evidence. Moreover, the increase of urban construction land due to transferred development rights might have significantly improved local

a: The graphical comparison of Nanchuan county of Chongqing between 2005 and 2015



b: The graphical comparison of Nancheng township of Nanchuan county between 2005 and 2015

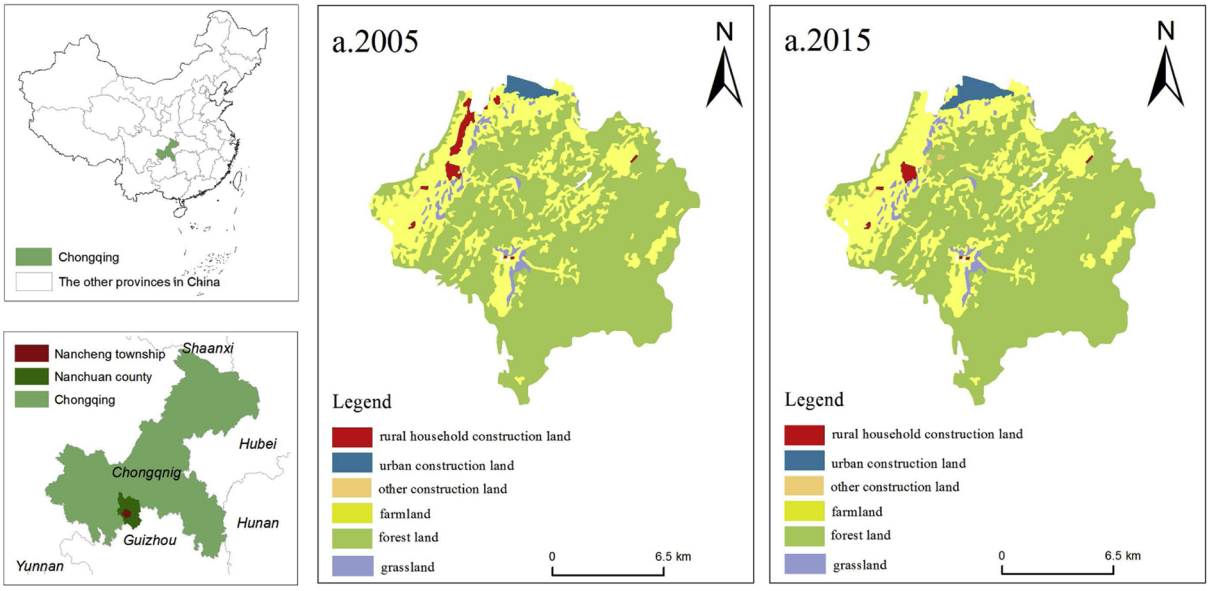


Fig. 8. a The graphical comparison of Nanchuan county of Chongqing between 2005 and 2015.
Note: The data is stored at Resource and Environment Data Cloud Platform of Chinese Academy of Science (CAS). b. The graphical comparison of Nancheng township of Nanchuan county between 2005 and 2015.
Note: The data is stored at Resource and Environment Data Cloud Platform of Chinese Academy of Science (CAS).

economic performance through improved industry agglomerations and increased market size with more permanent migrants integrated into urban cities.

Taking all the evidence together, we argue that such a market-oriented land use policy innovation—TDR—could be an effective solution to address the development dilemma concerning land utilization, which many fast-growing emerging economies are facing today. In the context of China, we find that this market-oriented land utilization program should be further incorporated in the later reform of China's land use system, in which population, land, and industry should be integrated under a consistent unified development framework (Long et al., 2019). Specifically, within this unified development framework, the dual system barriers between urban and rural areas should be removed, and a unified urban–rural construction land market system should be established. The use of the TDR program, such as the *Chongqing* experience, could be expanded to an even broader level (e.g., the regional or national level) so that the overall land use efficiency (nationwide) could be further improved (Zhao, 1999; Liu et al., 2010a; Hu et al., 2011).

This land use policy innovation could be essential for China to achieve rural vitalization as a national development strategy (Long and

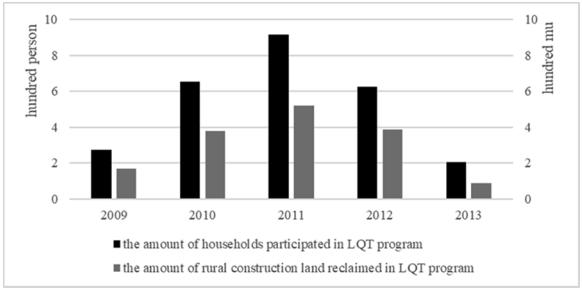


Fig. 9. Households participation in LQT program in Chongqing.
Note:
(1) Number is calculated based on the author's survey conducted in 2014. We randomly sampled 281 households from 23 LQT program villages, which have joined the LQT program during 2009-2013.
(2) We calculate two primary indicators from the village-level survey: the number of households participated in LQT program, and the amount of rural construction land reclaimed through LQT program during 2009-2013 in these villages.
(3) Data source: author's survey.

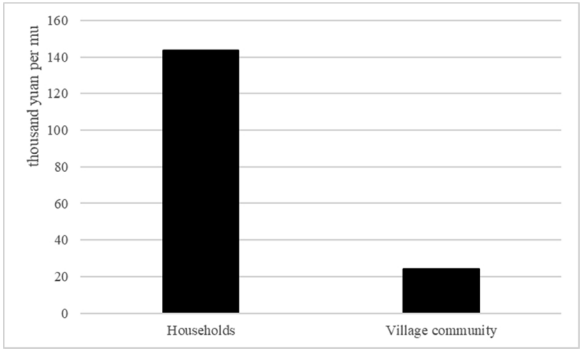


Fig. 10. Compensation division for participating in LQT program, thousand yuan per mu.
Note:
(1) The amount of compensation for reclaimed homestead is divided at 85:15 ratio between individual household and the village community (as the landowner). The amount of total compensation is, by theory, depending on the auction results.
(2) Compensations to the village community are used for rural public services, such as village trash processing costs, clean water program, and other public goods and services provisions.
(3) Data source: author's survey.

Qu, 2018), since one of the core objectives of rural vitalization is to establish an integrated dynamic development framework, in which people (human resources), land (natural resources), and industry (economical capital) could be combined in a sustainable approach. Implementing a program for the transfer of development rights as an institutional innovation has naturally linked people's demand for land (either urban construction land or rural farmland) with population movement and industry development. It has also facilitated sustainable natural resource use in the urban–rural transformation and reconstruction process in China (Liu, 2018). More studies could be further conducted to explore how to integrate the use of TDR in other regions of China to push forward rural revitalization, wherein people's needs are met, land use efficiency is enhanced sustainably, and the industry is developed more sustainably.

However, despite our study being carefully conducted, there are still several crucial limitations. First, using SCM does not allow us to assess the statistical significance of the results using standard (large sample) inferential techniques because the number of observations is usually quite small in comparative case studies. However, SCM enabled us to conduct a high-quality case study of the TDR program with long-term data to examine its dynamic effects. More rigorous evaluation approaches are needed to examine the program's environmental and socioeconomic effects. Second, many studies argued that these TDR programs are biased toward development rather than conservation (Linkous, 2016). In our study we have shown that setting the conversion ratio to less than one significantly improves farmland preservation. We argue that the use of TDR as an instrument is a management decision, which could be geared either toward development or preservation. However, we should not neglect the efficiency of TDR in land use planning. Third, other studies tended to discuss the implication of the TDR program on land property rights in a developing country's context (Li, 2008; Dharmavaram, 2013). From our study, it is hard to directly answer such a criticism since we did not collect household information concerning land property issues. Last but not least, much of the criticisms come from the TDR program's potential impact of degradation of cultivated land. Low quality reclaimed farmland might be much less fertile than previously cultivated land around urban fringes (Wang et al., 2012; Song and Pijanowski, 2014). Indeed, policymakers might need to take into account this potential problem since fertile land around the urban fringe, compared with reclaimed rural construction land, is much more productive for purposes of food production. Therefore, more innovative TDR experiments should be designed and evaluated to yield better and more comprehensive knowledge on the use of TDR in emerging economies.

CRediT authorship contribution statement

Bo Wang: Conceptualization, Investigation, Data curation, Writing - original draft. **Fan Li:** Methodology, Software, Formal analysis, Writing - review & editing. **Shuyi Feng:** Supervision, Project administration, Writing - review & editing. **Tong Shen:** Data curation, Validation.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104611.

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